THE OSTEOLOGY OF SINOPA, A CREODONT MAMMAL OF THE MIDDLE EOCENE.

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INTRODUCTION.

During the summer of 1902 the writer, assisted by Mr. Walter Granger, spent some weeks in the Bridger basin in southwestern Wyoming, with the object of determining faunal levels in the Bridger formation. This work was undertaken under the auspices of the U. S. Geological Survey and under direction of Prof. H. F. Osborn, palaeontologist of the Survey. Although collecting was not the principal object of the expedition, a number of fossils were secured, among which the most important was the finely preserved and nearly complete skeleton of *Sinopa*, found by Mr. Granger. The specimen was extracted from the matrix by Mr. Charles Christman and very skillfully prepared for mounting by Mr. Albert Thomson, both of the American Museum of Natural History. I owe the privilege of describing this rare specimen, which is one of the most perfect fossil skeletons ever discovered in an Eocene formation, to the courtesy of Dr. G. P. Merrill, Head Curator of Geology of the National Museum, and of my honored teacher and friend, Professor Osborn.

The genus *Sinopa* was the first carnivore to be described from the Eocene of this continent. It is the most abundant and characteristic creodont in the Bridger formation and is represented by a number of well-defined species in the Lower and Middle Eocene of North America. It has also been found in the Egerkingen beds of Switzerland, probably Middle Eocene, along with the related genus *Proviverra*. It is not known to occur in any Upper Eocene beds either in Europe or America, but in the Phosphorites of France, of approximately Lower Oligocene age, the closely allied genus *Cynohyænodon* is quite common.

LIST OF SPECIES OF SINOPA AND ALLIED GENERA.

[The names and dates are those of the original description. Indeterminate species are placed in brackets.]

1862. *Proviverra typica* Rütimeyer. Egerkingen beds, Switzerland.
June 21, 1871. [*Triacodon fallax* Marsh.] Bridger formation, Wyoming.
July 11, 1871. *Sinopa rapax* Leidy. Bridger formation, Wyoming.
July 29, 1872. [*Triacodon aculeatus* Cope.] Bridger formation, Wyoming.
Aug. 3, 1872. *Stypolophus pungens* Cope. Bridger formation, Wyoming.
Aug. 7, 1872. *Limnocyon agilis* Marsh. Bridger formation, Wyoming.
Aug. 7, 1872. *Stypolophus brevicalcaratus* Cope. Bridger formation, Wyoming.
Aug. 7, 1872. [*Stypolophus insectivorus* Cope.] Bridger formation, Wyoming.
Aug. 7, 1872. [*Triacodon grandis* Marsh.] Bridger formation, Wyoming.
Aug. 7, 1872. [*Triacodon nanus* Marsh.] Bridger formation, Wyoming.
1873. *Cynohyænodon cayluxi* Filhol. Phosphorites, France.
1873. *Cynohyænodon minor* Filhol. Phosphorites, France.
1874. *Prototomus viverrinus* Cope. Wasatch formation, New Mexico.
1875. *Prototomus secundarius* Cope. Wasatch formation, New Mexico.
1875. *Prototomus multicuspis* Cope. Wasatch formation, New Mexico.
1875. *Prototomus strenuus* Cope. Wasatch formation, New Mexico.
1877. *Stypolophus hians* Cope. Wasatch formation, New Mexico.
1882. *Stypolophus whitiæ* Cope. Wind River formation, Wyoming.
1892. [*Proviverra americana* Scott.] Bridger formation, Wyoming.
1901. *Sinopa opisthotoma* Matthew. Wasatch formation, Wyoming.
1902. *Sinopa major* Wortman. Bridger formation, Wyoming.
1902. *Sinopa minor* Wortman. Bridger formation; Wyoming.
Sinopa grangeri infra. Bridger formation, Wyoming.

HISTORY AND NOMENCLATURE.

Proviverra Rütimeyer, type *P. typica*, was the first genus described. It was based upon the anterior part of a skull in fairly good preservation. The additional material referred to this genus is very incomplete and its identification doubtful.

Sinopa Leidy, type *S. rapax*, was based upon an incomplete lower jaw. The first mention of the genus includes about a half a page of description and the type was figured two years later. This specimen has since been mislaid, but Leidy's excellent figures enable us to identify more complete specimens in the American Museum collections and differentiate the genus from *Proviverra*. The skeleton described in this article represents a new species of *Sinopa*. *S. opisthotoma* Matthew also belongs here but is subgenerically distinct.

Triacodon Marsh, type *T. fallax*, described shortly before *Sinopa*, was founded upon the trigonid of a lower molar which may belong to *Sinopa*, *Uintacyon*, *Limnocyon*, or some other creodont or carnivore. It is quite indeterminate. Three other species have been referred to the same genus and are equally indeterminate.

Stypolophus Cope, type *S. pungens*, was based upon a part of the lower jaw of a species closely allied to *Sinopa rapax*, of which the genus is a synonym.

Prototomus Cope, type *P. viverrinus*, was based upon a palate and fragments of the skeleton in bad preservation and was subsequently referred by its describer to *Stypolophus* (=*Sinopa*).

Cynohyænodon Filhol is nearly allied to *Sinopa* and *Proviverra*, but may be held as generically distinct from either. The type is a finely preserved skull, and other excellent material illustrates the genus.

The definitions will be as follows:

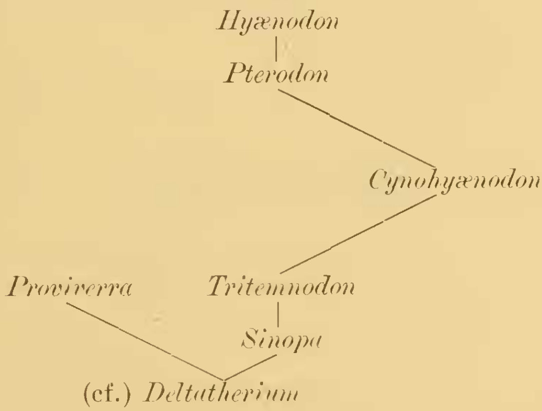
Family Hyænodontidæ. Carnassial teeth, M $\frac{2}{3}$.

I. M ^{3} absent, protocones and metaconids absent .... *Hyænodon*

II. M ^{3} transverse.

- A. Cusps massive, protocones and metaconids reduced, carnassials large, anterior molars small, transverse molar small .... *Pterodon*
- B. Cusps sharp, protocones and metaconids well developed, transverse molar larger. Molars of more equal size, with broad external cingula.
  1. Paracone and metacone connate on M $^{1-2}$, metacone vestigial on M ^{3}.
     - *a.* No metaconid on P $_4$ .... *Proviverra*
     - *b.* Metaconid on P $_4$ well developed; premolars long .... *Tritemnodon*, new genus.
     - *c.* Metaconid on P $_4$ well developed; premolars high .... *Cynohyænodon*
  2. Paracone and metacone well separated on M $^{1-2}$, metacone well developed on M^3 .... *Sinopa*

These genera show the different stages in the development of the highly specialized flesh-cutting teeth of *Hyænodon* from the comparatively primitive opossum-like teeth of *Sinopa*. Arranged according to cusp development, they stand thus:



This is in partial but not complete correspondence with their known geological occurrence, as follows:

Name.	Eocene.				Oligocene.	
	Basal.	Lower.	Middle.	Upper.	Lower.	Middle.
Hyænodon				×	×	×
Pterodon				×	×	
Cynohyænodon					×	
Tritemnodon		×	×			
Proviverra			×			
Sinopa		×	×			
Deltatherium	×					

The genus *Sinopa* has been held to include *Stypolophus* and *Prototomus* of Cope, and until lately *Limnocyon* Marsh.[a] Wortman in 1902 showed that the type species of *Limnocyon* belongs to a distinct group of the Creodonta, but referred *L. agilis* Marsh to *Sinopa* and described the skull and parts of the skeleton from two finely preserved specimens. The more complete material of *S. rapax* in the American Museum collections, and the complete skeleton here described, show such considerable differences from *S. agilis* that it seems necessary to separate them generically, splitting up the genus *Sinopa* into two closely allied genera, each represented by a number of species in both Middle and Lower Eocene. The generic distinctions are clear enough in the Middle Eocene, but in the Lower Eocene the species are not clearly separable, and most of them show various combinations of the characters of the two groups. *Sinopa rapax* Leidy is the type of the first, and *Tritemnodon* (*Limnocyon*) *agilis* Marsh will stand as type of the second group. See figs. 1 and 2.

DESCRIPTION OF THE SKELETON.

The entire skeleton is preserved except one fore and one hind foot and the distal half of the tail, of which only a few fragments remain. Most of it is in remarkably fine preservation. As found in the rock, the greater part of the vertebral column, pelvis, and most of the limbs were articulated together; the skull and jaws and some limb or foot bones were scattered; and several anterior dorsals and cervicals and most of the ribs were scattered and more or less broken up and damaged. The bones were very little crushed, and the articulations of the vertebræ so perfect that the sequence of those found out of place could be accurately determined.

The skeleton compares for size and proportions with the civet. The skull is elongate and rather large. The limbs are small and moderately slender, the neck of moderate length, the trunk long and slim, the tail extremely long and powerful. The vertebral formula is C 7, D 13, L 7, S 3, C ? 29. The fore and hind feet are five-toed, the digits rather slender, not spreading, except the first, which is somewhat divergent but not reduced in length. The scaphoid lunar and centrale are separate.

DENTITION, DEFINITION, AND SPECIFIC DISTINCTIONS.

SINOPA GRANGERI, new species.

Somewhat larger and more robust than *S. rapax*, with more massive teeth and a diastema behind P_2. Skull about equal in size to *Tritemnodon agilis*, but shorter, considerably deeper in the facial region, with higher sagittal crest and deeper jaw. Premolars less compressed,

[a] Cope, Scott 1892, Matthew 1901.

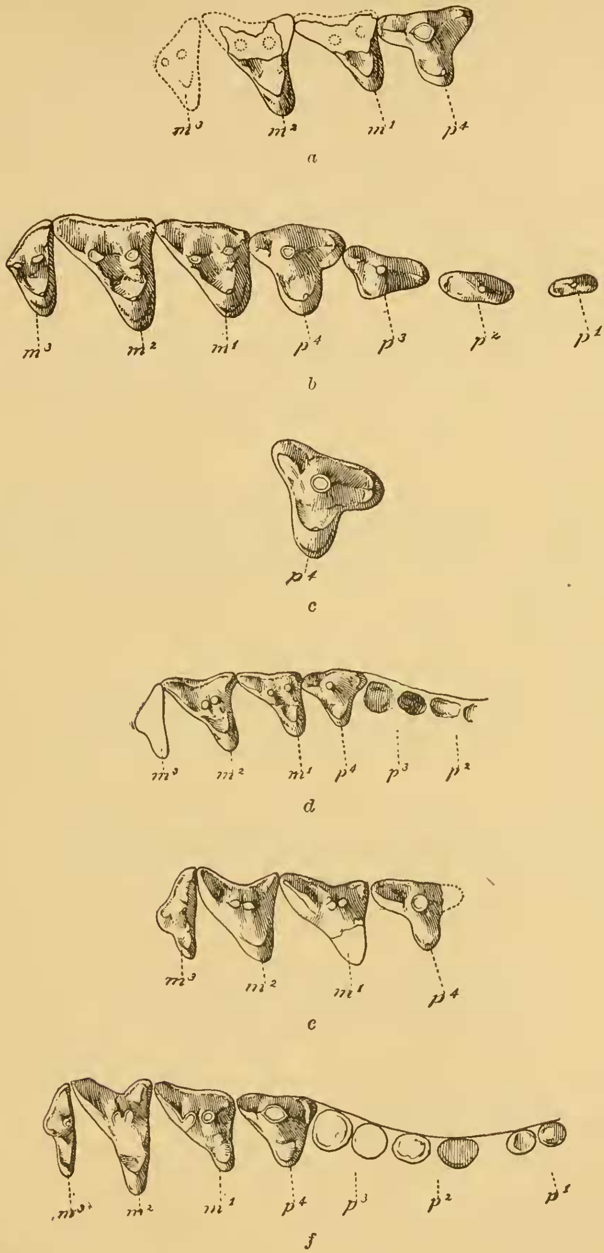


FIG. 1.—UPPER TEETH OF SPECIES OF SINOPA AND TRITEMNODON, NAT. SIZE, CROWN VIEWS. FROM THE SAME INDIVIDUALS AS THE LOWER TEETH SHOW IN FIG. 2.

a, *Sinopa rapax* Leidy, Am. Mus. Coll., No. 11535. *b*, *Sinopa grangeri*, new species. Type. Cat. No. 5341, U.S.N.M. Coll. *c*, *Sinopa major* Wortman, Am. Mus. Coll., No. 11538. *d*, *Sinopa minor* Wortman, Am. Mus. Coll., No. 11532. *c*, *Tritemnodon agilis* Marsh, Am. Mus. Coll., No. 11543. *f*, *Tritemnodon whitiæ* Cope, Am. Mus. Coll., No. 4781.

paracones and metacones of upper molars well separated, heels of lower molars much larger than in *T. agilis*, metacone on M^3 well developed. Skeleton smaller with shorter limb-bones.

Teeth. (fig. 1*b*, 2*c*) Dentition $\frac{3 \cdot 1 \cdot 4 \cdot 3}{3 \cdot 1 \cdot 4 \cdot 3}$. Incisors small, transverse, canines slender and of moderate size. Premolars trenchant, moderately compressed, P^3 two-rooted, but of subtriangular outline with rudimentary internal cusps. P^4 three-rooted with large lunate internal cusp, small antero-external and larger postero-external basal cusps and massive conical protocone. Molars functionally resembling those of the opossum, but only three in number, with principal oblique and subordinate transverse shears, the upper ones of triangular outline, paracone and metacone of equal size and well separated, large lunate antero-internal protocone, and broad external cingular shelf. M^{1-2} sub-equal, with small paraconule and metaconule, parastyle small, metastyle extended into a strong shearing blade. M^3 smaller, transverse, metacone well developed but smaller than paracone, no metastyle, parastyle extended into a short shearing blade, no metaconules. Lower molars of nearly equal size, but M_1 smaller than the others, the trigonids high, of triangular form, paraconid and metaconid well developed, sub-equal, protoconid overtopping both. Heels basin-shaped, as large as the trigonids, except on M_3.

In *S. rapax* (fig. 1*a*, 2*a*) the internal cusps of P^4 to M^3 are more compressed and less broadly lunate, the principal cusp of P^4 is less massive, the heels of the lower molars are smaller, and there is no diastema behind P_2. In *T. agilis* (fig. 1*e*, 2*f*) the internal cusps of the upper teeth are smaller and much more compressed, P^3 is compressed and trenchant, the paracone and metacone are closely connate and of unequal size, metacone absent on M^3, heels of lower molars much smaller, metaconids greatly reduced, etc. In *T. whitiæ* (fig. 1*f*, 2*g*) the inner cusps of the molars are extended inward, the metaconids well developed, but otherwise it is much as in *T. agilis*. The Lower Eocene species exhibit a further approach toward the true *Sinopa* in one or another feature, but all are nearer to *S. rapax* than to the species here described. *S. major* of the Bridger (fig. 1*c*, 2*d*) is larger and more massive than *S. grangeri*, with lower crowned teeth, broad heels to the lower molars, etc.

SKULL, DESCRIPTION AND COMPARISONS.

The skull is elongate in both facial and cranial regions, with narrow muzzle, small brain case, moderately high sagittal and occipital crests, short and rather slender arches, strong postorbital constriction. The premaxillæ are deeply excavated for the reception of the lower canines, the borders of the excavation very strongly marked; their ascending processes are very slender and extend backward only to a point above P^1. The nasals are slightly expanded in front, and somewhat more

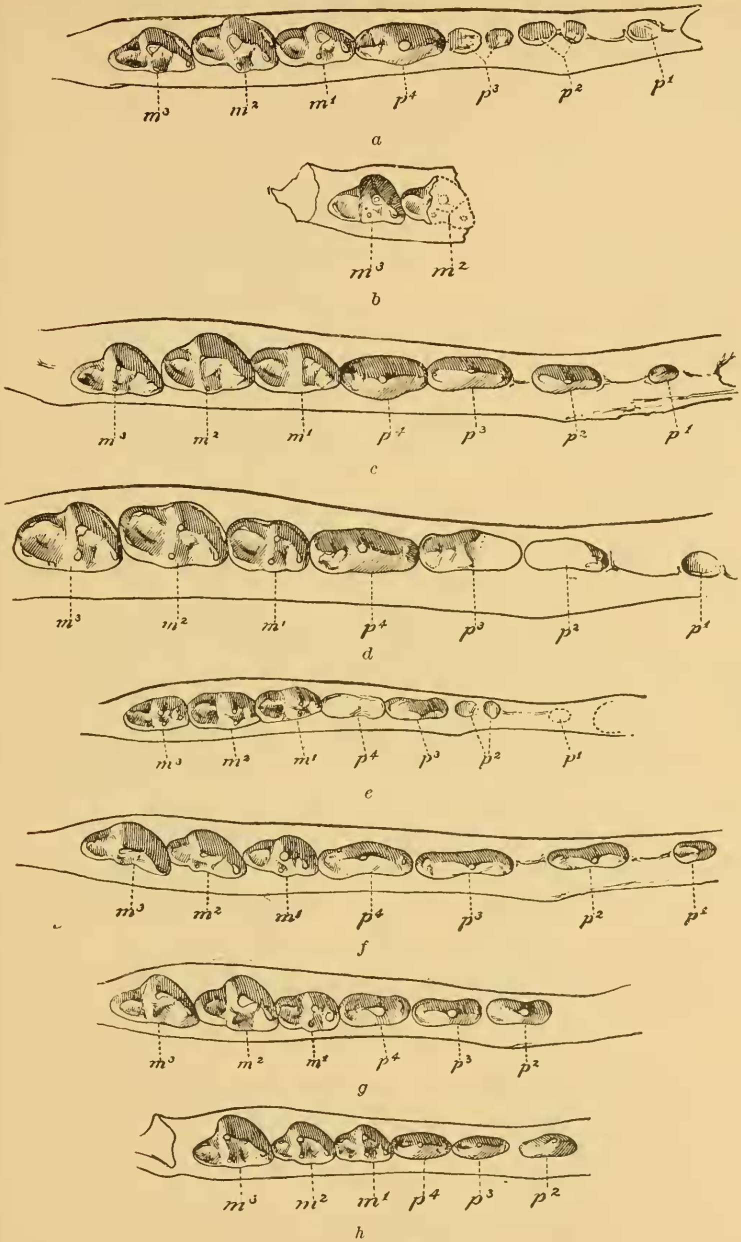


FIG. 2.—LOWER TEETH OF SPECIES OF SINOPA, TRITEMNODON, AND CYNOHYÆNODON. NAT. SIZE, CROWN VIEWS.

a, *Sinopa rapax* Leidy, Am. Mus. Coll., No. 11535. *b*, *Sinopa pungens* Cope. Type. Am. Mus. Coll., No. 5015. *c*, *Sinopa grangeri*, new species. Type. Cat. No. 5341 U.S.N.M. Coll. *d*, *Sinopa major* Wortman, Am. Mus. Coll., No. 11538. *e*, *Sinopa minor* Wortman, Am. Mus. Coll., No. 11532. *f*, *Tritemnodon agilis* Marsh, Am. Mus. Coll., No. 11543. *g*, *Tritemnodon whitiæ* Cope, Am. Mus. Coll., No. 4781. *h*, *Cynohyænodon cayluxi* Filhol, Am. Mus. Coll., No. 11055.

expanded posteriorly, but to nothing like the extent seen in the Mesonychidæ or Marsupialia. The *lachrymals* have a broad semicircular expansion upon the face, but the foramen is completely within the orbit. This condition appears to be generally characteristic of the Creodonta. In true Carnivora the lachrymal has a very slight expanse on the face, the maxillary coming nearly or quite to the margin of the orbit. In the carnivorous marsupials there is some expansion of the lachrymal upon the face, but in this group, as in the Insectivora, the lachrymal foramen is more or less external to the orbit. A much closer approach is seen among the Ungulata, where the lachrymal has a very large facial expansion, the foramen entirely intra-orbital, and the tubercle on the margin of the orbit. The form and extent of the facial part of the lachrymal approaches that in *Sinopa* most nearly in the primitive types—Oreodon, Dacrytherium, Agriochœrus, Hyrachyus, etc. In the more elongate skulls of later Ungulates it becomes much more expanded.

The facial expansion of the lachrymal appears to be correlated with the position of the orbits, which in *Sinopa*, as generally among the Creodonta, are farther back than in modern Carnivora. In *Sinopa* they lie above $M^{\underline{1-3}}$; in *Canis* they are above $P^{\underline{4}}$-$M^{\underline{2}}$; in *Viverra* above $P^{\underline{3}}$–$M^{\underline{2}}$; in the opossum above $M^{\underline{2-4}}$. In Ungulata they are above or behind the molars, and the extension of the lachrymal on the face varies in accordance.

The frontals are short, extending back on the top of the skull only to the posterior part of the temporal crests and forming no portion of the sagittal crest. At the sides they extend but slightly farther back, to the postorbital constriction, which is immediately behind the anterior end of the sagittal crest. They are broad anteriorly and inflated above the orbits, leaving a marked depression along the median line, deepest in front of the sagittal crest and shallowing out as it approaches the posterior margin of the nasals.

The parietals are remarkably long, extending well down on the sides of the skull and including the whole of the sagittal crest.

The premaxillaries are large, with wide ascending portions and moderately large infraorbital foramen situate above $P^{\underline{3}}$; the muzzle in front of this is compressed and deep; behind this point the skull expands rapidly as in *Daphænus* and the Canidæ generally.

The jugal is of moderate size and rather long; its anterior branch extends under the orbit and has a considerable contact on the face with the lachrymal, thus excluding the maxilla from any near approach to the orbit; the inferior branch is short, the posterior branch extends backward beneath the zygomatic process of the squamosal nearly to the glenoid fossa, ending in a slender splint, as among the Carnivora generally. In the opossum its posterior end is thickened and forms a considerable part of the anterior side of the glenoid fossa, while a short process also extends backward above the zygomatic process of the squamosal.

The brain case is larger than in the opossum, but as in that animal the cerebral lobes were entirely contained within the parietals above, the frontals surrounding the olfactory lobes only. The elongate

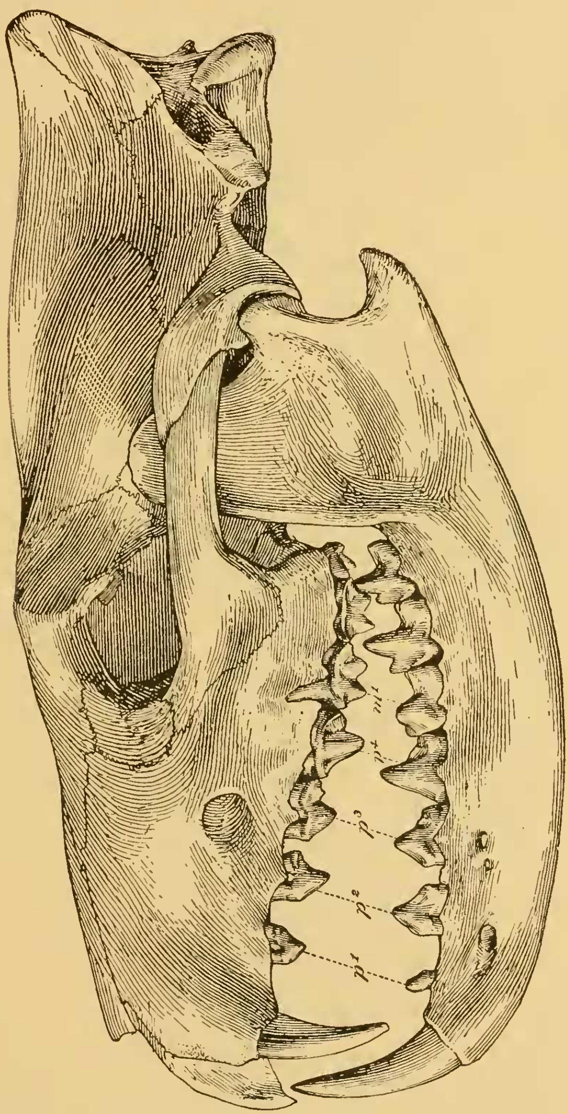


FIG. 3.—SINOPA GRANGERI, SIDE VIEW OF SKULL AND JAWS, NAT. SIZE.

cranial portion of the skull causes the arrangement of the cerebellar lobes to be entirely different from that of the opossum or of the insectivora, corresponding more with that in the Oligocene Carnivora. The cerebral lobes, however, are much smaller than in any of these.

The basicranial region is long, a feature eminently characteristic of the Carnivora, and distinguishing them sharply from either marsupials or insectivores. In practically all modern carnivora the arrangement of the basicranial bones and foramina is obscured or modified by the

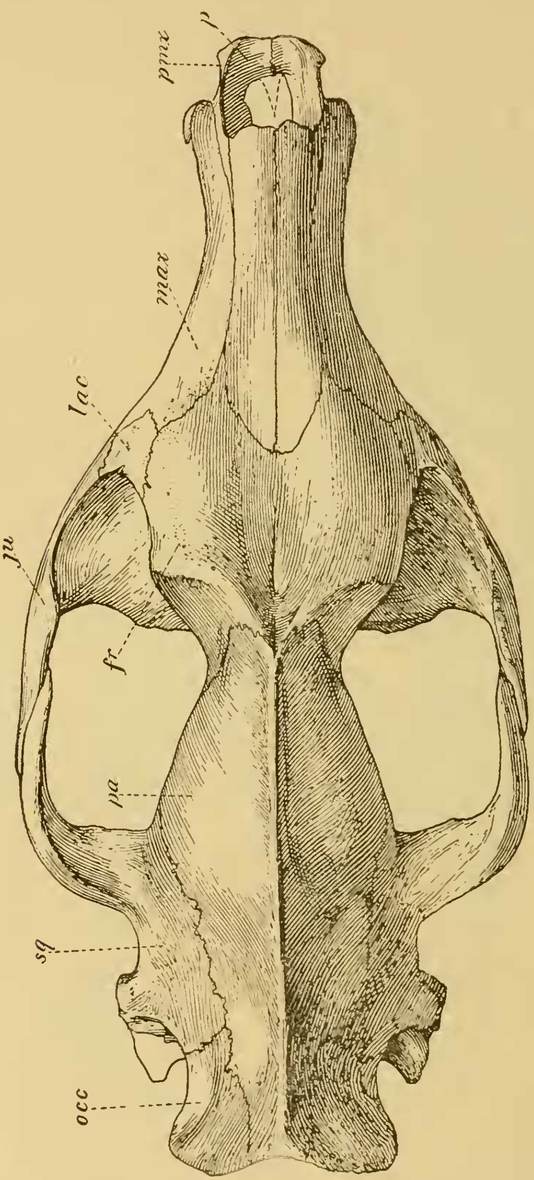


Fig. 4.—*Sinopa grangeri*, top view of skull, nat. size. *fr*, frontal; *ju*, jugal; *lac*, lachrymal; *max*, maxilla; *occ*, occipital; *pa*, parietal; *p* and *pmx*, premaxillaries, and *sq*, squamosal bones of the skull.

development of tympanic bullæ. In *Sinopa* the bullæ are absent, giving a singularly primitive appearance to this part; they were either not ossified at all or were loosely attached to the skull. The bullæ are not developed in marsupials nor in most Insectivora, but in both these groups are frequently present false bullæ formed by processes of the alisphenoid, partially replacing the true tympanic bullæ. No sign of

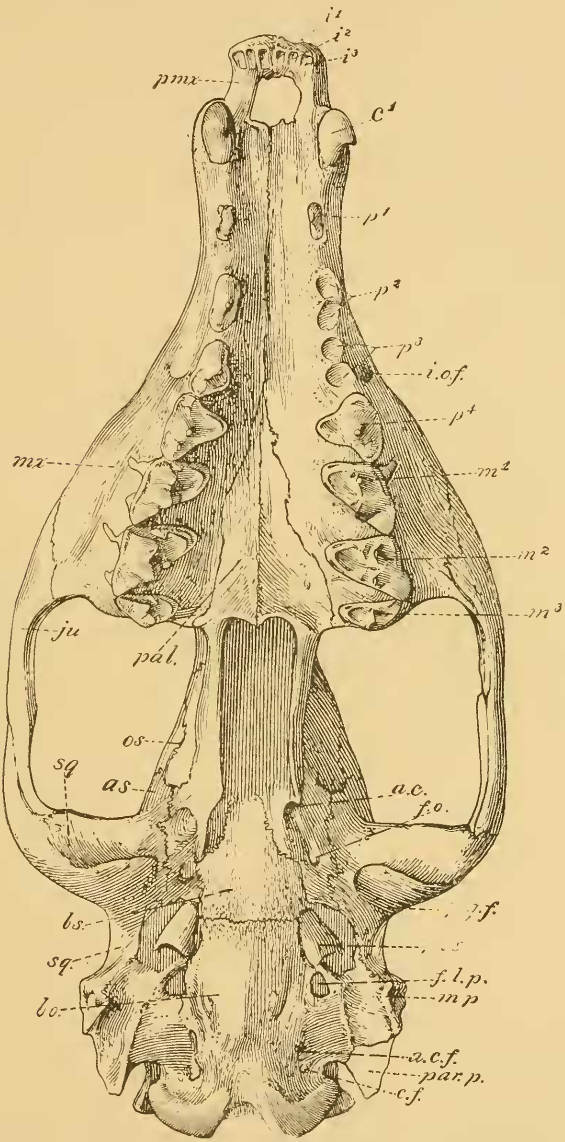


FIG. 5.—SINOPA GRANGERI, INFERIOR VIEW OF SKULL, NAT. SIZE. *a. c.*, ALISPHENOID CANAL; *a. c. f.*, SUPPOSED ANTERIOR CONDYLOID FORAMEN; *as*, ALISPHENOID (THE DOTTED LINE IS NOT CARRIED FAR ENOUGH); *bo*, BASIOCCIPITAL; *bs.*, BASISPHENOID; *c*, CANINE; *c. f.*, CONDYLOID FORAMEN; *f. l. p.*, FORAMEN LACERUM POSTERIUS, *f. o.*, FORAMEN OVALE; *i 1, 2, 3*, INCISORS; *i. o. f.*, INFRA-ORBITAL FORAMEN; *ju*, JUGAL; *m 1, 2, 3*, TRUE MOLARS; *mp*, MASTOID PROCESS OF THE PERIOTIC; *mx*, MAXILLA; *os*, ORBITOSPHENOID; *p 1, 2, 3, 4*, PREMOLARS; *pal*, PALATINE; *par. p.*, PAROCCIPITAL PROCESS OF THE EXOCCIPITAL BONE; *pet*, PETROSAL PROMINENCE OF THE PERIOTIC BONE; *p. g. f.*, POSTGLENOID FORAMEN; *pmx*, PREMAXILLA; *sq*, SQUAMOSAL.

these processes is seen in *Sinopa*, and there is little or nothing in this important region of the skull to indicate either marsupial or insectivore affinities. On the other hand, if we compare it with the Oligocene dog *Daphænus*, in which only the smaller or true tympanic chamber of the skull was ossified, and this so loosely attached to the skull that it is rarely preserved, we find a very close correspondence indicative of real relationship, while the numerous and important points of difference from Insectivora and especially from marsupials indicate a remote origin of the divergence from these groups.

The basioccipital is long and broad. The broad flattened paroccipital processes arise considerably in advance of the condyles and project backward to a short point. In *Daphænus* the basioccipital is even longer; the paroccipitals have the same position and form, but curve downward at the tips. In *Didelphys* they arise almost opposite the condyles and project straight downward. In *Cynodictis* they project backward and are otherwise similar. In modern carnivora the tips usually extend farther downward and are soldered to the bulla. In *Erinaceus* and *Centetes* they have the more posterior position and project downward in the former, outward and backward in the latter. The condyloid foramen is situate considerably in advance of the condyles, as in carnivora generally. In marsupials and Insectivora it is close under the projecting border of the condyle, and in the former has an accessory foramen, also entering backward, close in front of it. In front of the condyloid foramen in *Sinopa* is a well-marked foramen entering forward, which Wortman homologizes with the accessory condyloid foramen of marsupials in spite of its opposite direction and quite different position in the bone. It appears to me much more probable that this foramen transmits one of the nerves or arteries which in later Carnivora pass through the jugular foramen (*for. lac. post.*), with which it corresponds in direction and from which it is not far removed. Indeed, in *Daphænus*, the condyloid foramen is a little farther forward and on the posterior border of the posterior lacerate foramen is a notch entirely corresponding to the remains of this accessory foramen, if, as I suppose, it has become fused with the lacerate. A similar notch is seen in *Hyaenodon*, where the backward displacement of the glenoid fossæ has crowded the parts behind them toward the condyle. The basisphenoid is not pierced by the carotid canal—an important distinction, as Wortman observes, from the marsupials; and he believes from indications seen on his specimen, but which I am unable to corroborate from this one, that its course was similar to that in true Carnivora, entering finally at the median lacerate foramen. The petrosal prominence is pear-shaped, the small end antero-internal; near the posterior end is the fenestra rotunda, exterior and a little in front of it the fenestra ovalis, and on the antero-exterior slope of the prominence a smaller foramen which I do not recognize. Outside of the petrosal prominence is a long, deep fossa bounded anteriorly by the alisphenoid, externally by the glenoid portion of the squamosal, posteriorly by the mastoid portion of the periotic. At the bottom of this fossa lie the stylomastoid foramen and another foramen or deep fossa which I do not recognize. Behind the prominence lies the large oval posterior lacerate (jugular) foramen. The mastoid processes are of moderate size, short and stout, and extend, wing-like, outward and partly downward; posteriorly they are confluent with the bases of the paroccipitals. The postglenoid processes resemble the corresponding parts in *Daphænus*; the postglenoid foramen is of moderate size. The foramen ovale is rather large and is situate opposite the glenoid fossa, as in Carnivora; in Insectivora, and especially in marsupials, it is considerably in advance of it. The alisphenoid extends some distance behind the foramen ovale, wedged in between the basisphenoid and the glenoid portion of the squamosal, but it has no dependent process such as is seen in marsupials, and is especially developed in certain Insectivora. The posterior nares are not roofed over behind the molars, but the nareal canal is deep and broad, the pterygoid portions of the palatine and alisphenoid forming large dependent plates, as in Carnivora. The pterygoids proper are not preserved on this specimen. The pterygoid plates of the alisphenoid are variably developed in Insectivora, very slightly so in marsupials.

The palate is completely ossified. A number of minute (? nutritive) foramina on its surface are thought by Wortman to be an approach to the incompletely ossified palate of certain modern marsupials and some insectivores, but of this there seems to be no sufficient evidence. The posterior border of the palate is somewhat thickened, as in *Centetes* and *Myogale*, but has little resemblance to the posterior expansion and strong transverse crest seen in *Erinaceus* and *Didelphys*.

The occiput presents a very different appearance from that of the modern Canidæ and differs in much more essential respects from that of marsupials or Insectivora. The principal differences from the modern carnivore skull are apparently dependent upon the small development of the brain. The Oligocene Carnivora, and especially *Daphænus*, approach it much more closely. The early Ungulata also exhibit a considerable resemblance, but from Insectivora and marsupials it is separated by more radical features.

The exposure of the mastoid on the side of the skull is very small, scarcely extending above the mastoid process. The occipital surface is much contracted above the condyles, and above that flares out into a broad plate formed by the expanded occipital crests. These are continued downward and forward in strong lambdoid crests to the mastoid processes. Between the lambdoid crest and the condyle is a deep fossa bounded below by a strong crest connecting the outer ends of the condyle with the base of the paroccipital process. In *Daphænus* this deep fossa is largely filled up, presumably by expansion of the cerebellum from within; in *Canis* there is nothing left of it. In

Canis and other Carnivora there is a considerable lateral exposure of the mastoid; in *Canis* it faces partly backward. In the marsupials and in some Insectivora the exposure is entirely posterior, the squamosal (lambdoidal) crests continuing the occipital crest downward on each side and the mastoid exposure lying within them.

The lower jaw is unusually deep, with long loose symphysis extending back to a point beneath the anterior border of the third premolar. In the posterior portion it is quite like the long-jawed Carnivora in form, presenting none of the peculiarities of angle and coronoid seen in Insectivora, Chiroptera, and Marsupialia. The anterior and posterior mental foramina have the normal carnivore position, the former beneath the diastema between P_1 and P_2, the latter beneath $P_{\overline{3}}$. In certain Insectivora the posterior mental foramen is beneath $M_{\overline{1}}$. This unusual character appears to be of importance in indicating relationship.

Comparisons with Hyænodon.—The dentition of *Hyænodon* is very

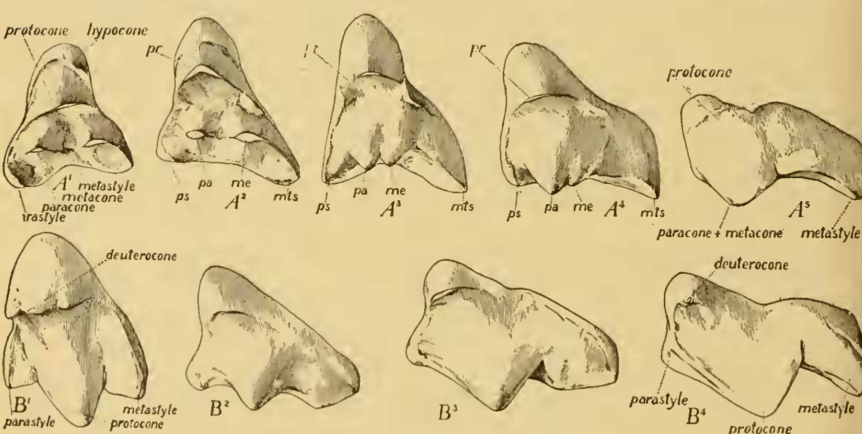


FIG. 6.—EVOLUTION OF THE UPPER CARNASSIAL IN CREODONTA AND CARNIVORA. SERIES *A*, HYÆNODONTIDÆ (SECOND MOLAR, RIGHT SIDE); *A*¹, DELTATHERIUM; *A*², SINOPA; *A*³, TRITEMNODON; *A*⁴, PTERODON; *A*⁵, HYÆNODON. SERIES *B*, CANIDÆ (FOURTH PREMOLAR, RIGHT SIDE); *B*¹, PALÆONICTIS; *B*², DIDYMICTIS; *B*³, DAPHŒNUS; *B*⁴, CANIS. THE CARNASSIAL OF FELIS, NOT INCLUDED IN THIS SERIES, IS MUCH MORE LIKE THE HYÆNODON CARNASSIAL.

[Published in advance, by courtesy of Prof. H. F. Osborn, from his forthcoming memoir upon Trituberculy.]

clearly derivable from that of *Sinopa*, through *Pterodon* and *Tritemnodon*, as Scott and Wortman have pointed out in various publications. The accompanying figures, drawn from models made by the writer, illustrate these stages in the evolution of the specialized carnassial of *Hyænodon*. The changes correspond in upper and lower teeth, and are exactly analogous to the development of the carnassial in the true Carnivora. In the upper teeth the two series begin in teeth of widely different form and end in very similar teeth, furnishing one of the most striking examples known of true convergent adaptation, in that it results in the production of similar form from originally dissimilar types, as distinguished from the far more common instances of parallel adaptation.

As has already been intimated, the geological occurrence of the known species forbids their being considered as in direct genetic sequence; but the genera may be properly so regarded (except *Deltatherium*), and the features of skull and skeleton entirely accord with the teeth in indicating a direct genetic sequence of the genera.

The species of *Hyænodon* differ very considerably in certain adaptive features of the base of the skull, dependent upon the pushing backward of the glenoid articulation to a position almost opposite the occipital condyles. In all of them, and in *Pterodon* as well, the basioccipital is somewhat shorter than in *Sinopa* and the petrosal prominence of irregularly rounded form, situate at the bottom of a deep pit. The posterior nares are roofed over to a varying extent by union of the pterygoid plates of the palatines and alisphenoids. The tympanic bulla is ossified to a varying degree. The fossa between the condyles and lambdoidal crests is filled up as in *Daphænus*. The limbs show a more or less cursorial adaptation. These features are developed to the greatest extent in the large American species *H. horridus;* the European *H. brachyrhynchus* is the most primitive (except that the bulla is completely ossified according to Filhol's statement). A skeleton from Colorado referred to *H. cruentus* shows a mere ring of ossification of the tympanic, while in other species the bulla was complete but small (according to Scott). *H. paucidens* is the most primitive of the American species.

Pterodon is much like *Hyænodon* in the features of the base of the skull, but has the united mastoid and paroccipital processes extended into broad wing-like "jugular apophyses" (Filhol), while in *Hyænodon* they are less developed than in *Sinopa*. The fossa behind the lambdoids is deep, the post-nareal gutter narrowed anteriorly but not roofed over, and in other respects the skull is very primitive, but resembles the primitive species of *Hyænodon* and differs from *Sinopa* in the details of form of the bones and processes.

Tritemnodon is very close to *Sinopa* in all the details of skull and skeleton structure, as may be seen by comparison of the figures and description of *T. agilis* given by Wortman.

Cynohyænodon is near to *Sinopa* and *Tritemnodon*, but has a shorter basicranial region and larger brain case. It appears from Filhol's figures of *C. cayluxi* to show various other distinctions from these genera in the form of the otic region and arrangement of the foramina, as well as in the shorter, higher crowns of the premolars, all placing it more directly in the ancestral line of *Hyænodon* and *Pterodon*.

VERTEBRAL COLUMN, DESCRIPTION AND COMPARISONS.

Cervical vertebræ.—The atlas is short with wide transverse processes, which are well expanded anteriorly, but not extended posteriorly as much as in most modern carnivora. The posterior opening of the vertebrarterial canal faces backward on the posterior margin of the tranverse process, as in all carnivora except the Miocene and later dogs. The remaining features are those usually found in Carnivora. It nearly resembles *Hyænodon* in proportions and form; in the cat the transverse processes have the same shape and position, but the body is a little longer; in *Canis* and *Daphænus* the transverse processes extend more posteriorly; in *Viverra* the body is considerably longer, the transverse processes more posterior and less expanded. In the opossum and hedgehog the form of the processes is different and the vertebral artery does not perforate the bone.

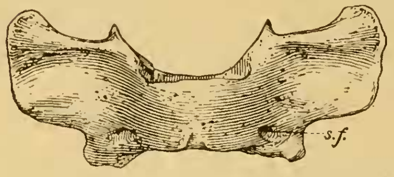


Fig. 7.—Sinopa grangeri, atlas viewed from above, nat. size. *s.f.* foramen for exit of 1st spinal nerve.

The axis is long, with high neural spine of the characteristic carnivore form, expanded into a broad plate extending forward as far as the tip of the odontoid and ending posteriorly in a stout backwardly directed spine. It is longer than in *Hyænodon* but somewhat shorter than in *Daphænus*, and shows no important distinctions from either.

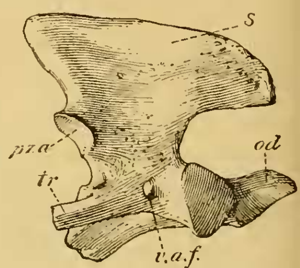


Fig. 8.—Sinopa grangeri, axis vertebra, side view, nat. size. *od*, odontoid process; *pza*, posterior zygapophysis; *s*, neural spine; *tr*, transverse process; *v. a. f.*, vertebrarterial foramen.

The remaining cervicals, except the seventh, have short spines, transverse processes with the inferior laminæ expanded into broad plates, and superior laminæ absent on the anterior ones, but moderately developed on the sixth. In the Carnivora the superior laminæ are generally distinct upon the third to sixth vertebræ, successively increasing in size. In the opossum the arrangement is more as in *Sinopa*, except that the inferior laminæ are less expanded. In *Daphænus* the upper laminæ are developed upon the fourth, fifth, and sixth; in *Canis* upon fifth and sixth; in Felidæ and Viverridæ upon all four. In the Machærodonts the superior lamina is not distinct upon any but the sixth, but the inferior lamina is less broad and plate-like.

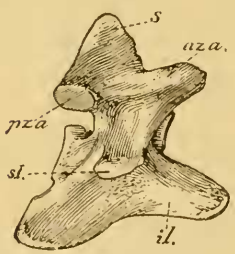


Fig. 9.—Sinopa grangeri, sixth cervical vertebra, nat. size, side view. *aza.*, anterior zygapophysis; *il.*, inferior lamella of the transverse process; *pza*, posterior zygapophysis; *s*, neural spine, and *sl.*, superior lamella.

The seventh cervical has a rather long spine, strong superior lamina, no inferior lamina, and is not perforated by the vertebrarterial canal. In this important feature, as well as in its general form, it agrees with the Carnivora and insectivores, and differs from marsupials.

The dorsal vertebræ number thirteen. The first ten have spines of moderate height, wider than in the dog or cat, higher than in *Viverra*, but not so wide. They decrease in height and increase in backward inclination to the tenth. Their transverse processes are rather large and stout, considerably expanded at the tips. The first is the most robust, the others of nearly equal size. The eleventh vertebra has no spine. Its anterior part and transverse processes resemble the anterior dorsals. Its posterior part resembles the dorsals and lumbars behind it. The twelfth and thirteenth are like the lumbars and have short flat spines directed forward.

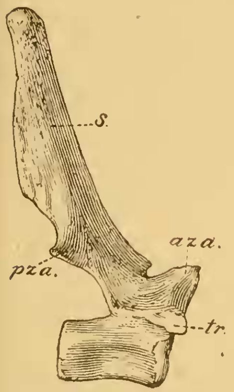


FIG. 10.—SINOPA GRANGERI, SECOND DORSAL VERTEBRA, SIDE VIEW, NAT. SIZE. *aza.*, ANTERIOR ZYGAPOPHYSIS; *pza.*, POSTERIOR ZYGAPOPHYSIS; *s.*, NEURAL SPINE; *tr.*, TRANSVERSE PROCESS.

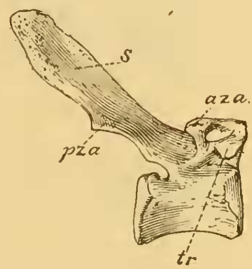


FIG. 11.—SINOPA GRANGERI, EIGHTH DORSAL VERTEBRA, SIDE VIEW, NAT. SIZE. *aza.*, ANTERIOR ZYGAPOPHYSIS; *pza.*, POSTERIOR ZYGAPOPHYSIS; *s*, NEURAL SPINE; *tr.*, TRANSVERSE PROCESS.

The lumbars are of large size; the centra long, except the seventh; the spines high and broad; the transverse processes long and directed forward, but not curved. The zygapophyses are large and strongly convex, but not revolute. This type of lumbar characterizes all Creodonts (except that in *Patriofelis* the lumbar zygapophyses are revolute). Among modern Carnivora it is retained to the greatest degree among the Viverridæ.

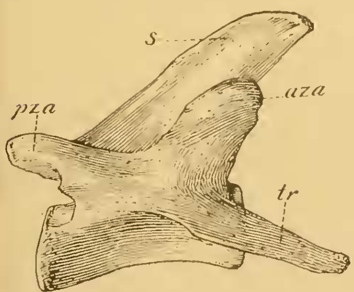


FIG. 12.—SINOPA GRANGERI, SIXTH LUMBAR VERTEBRA, SIDE VIEW, NAT. SIZE. *aza*, ANTERIOR ZYGAPOPHYSIS; *pza*, POSTERIOR ZYGAPOPHYSIS; *s*, NEURAL SPINE; *tr*, TRANSVERSE PROCESS.

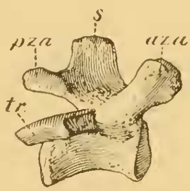


FIG. 13.—SINOPA GRANGERI, SECOND CAUDAL VERTEBRA, SIDE VIEW, NAT. SIZE. *aza*, ANTERIOR ZYGAPOPHYSIS; *pza*, POSTERIOR ZYGAPOPHYSIS; *s*, NEURAL SPINE; *tr.*, TRANSVERSE PROCESS.

The sacrum is composed of three vertebræ and is long and unusually large, especially the anterior sacral; the rib massive, expanded at its contact with the ilium. The posterior sacrals are not so large nor their transverse plates so wide. The second sacral takes a minor part in the iliac articulation by means of the forward end of its transverse process.

The caudals are preserved in series as far back as the seventeenth. The first four have large, strongly convex zygapophyses like those of the lumbars, long, stout transverse processes, and rather short bodies. The fifth and sixth show the change to the middle caudal region, in which the zygapophyses are simplified, the arches reduced, the centra increased in length and diminished in width, the transverse processes shortened and expanded antero-posteriorly into flat plates as long as the centra, and decreasing in width on each successive vertebra until on the seventeenth they are reduced to ridges on the sides of the centra. The neural arches are complete as far back as the thirteenth vertebra.

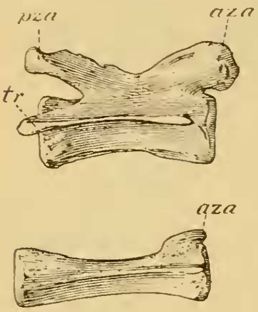


FIG. 14.—SINOPA GRANGERI, SEVENTH AND SIXTEENTH CAUDAL VERTEBRAE, SIDE VIEWS, NAT. SIZE. *aza*, ANTERIOR ZYGAPOPHYSES; *pza*, POSTERIOR ZYGAPOPHYSES; *tr*, TRANSVERSE PROCESS.

Comparisons with Hyænodon.—In the characters of the vertebral column *Sinopa* is nearer to *Daphænus* and *Cynodictis* than to *Hyænodon* or *Patriofelis*. It agrees with the two former in the large long lumbars, the general character of the spines and transverse processes of most of the vertebrae, proportions of sacrum, proximal caudal spines, etc.

Hyænodon differs in the superior and inferior laminæ of the transverse processes, distinct on cervicals 4–6; the lumbars smaller and shorter, their spines broader but not so high, their transverse processes much shorter, the sacrum much smaller, the tail much shorter, and lateral plates of middle caudals not prominent. All these features are probably due to adaptation to running, and are exactly paralled in the distinctions between the modern Canidæ and *Daphænus* or *Cynodictis*.

Patriofelis has shorter cervicals than *Sinopa*, lumbars large but short, their zygapophyses *revolute*, spines broader and wider at top, transverse processes short and stout. The sacrum is not so broad anteriorly, the caudals are massive, but not so long; the anterior ones have extremely broad, massive, transverse processes, while in the middle caudals the transverse lamellæ are reduced to short, stout anterior and posterior processes. The neural arch continues only to the ninth vertebra, a remarkable feature considering the length and power of the tail.

Oxyæna is proportioned much more like *Sinopa*, with similar type of dorsals, long and large lumbars, etc., but the skeleton is not complete enough to compare exactly.

Hoplophoneus has the transverse processes of the cervicals, including the atlas, greatly extended posteriorly. A distinct inferior lamina develops on C 5–6. The dorsals are not unlike *Sinopa*, but the posterior ones develop powerful anapophyses, which are continued into the lumbars with decreasing strength. The lumbars are not so long, their spines much like those in *Sinopa*, transverse processes considerably shorter. The sacrum is not so wide anteriorly, the spines higher. The transverse processes of the two first caudals are expanded into plates, in the next three they slant backward, and are not so stout as in *Sinopa;* the transverse lamellæ of the middle caudals are much less developed. The neural arches are continuous as far as the thirteenth caudal, but the middle caudals are smaller and the tail shorter.

RIBS AND STERNUM.

There are thirteen ribs. They are distinguished, especially the anterior ones, by exceptional shortness and rather broad, flattened shafts. The flattening of the shaft is more uniform from end to end than in dogs or viverrines, in which it is restricted to the distal middle section of a few ribs, and the others are much rounder and somewhat more slender and elongate. I do not find any Carnivora presenting the rib features of *Sinopa*. They do not appear to be marsupial characters, but are seen in early ungulates and (except the length) highly developed in the more recent ones.

Five sternal segments are preserved. All of them are of the narrow elongate type usually seen in Carnivora, and show none of the flattening observed by Wortman in *Mesonyx* and mentioned by him as a characteristic marsupial feature. It is also characteristic of most ungulates and of many other groups.

APPENDICULAR SKELETON, DESCRIPTION AND COMPARISONS.

Forelimb.—The limbs are remarkably small in comparison with the proportions of skull and backbone. They do not exceed those of a large domestic cat in length, although somewhat stouter, while the backbone (exclusive of the tail) is one-fourth longer than in that animal and the skull nearly twice as long.

The scapula is incomplete, the anterior border not being preserved on either side. Its general form, so far as comparison can be made, agrees best with *Canis*, being rather long and narrow for a carnivore, and the upper border at right angles to the posterior. The spine is about as high as in *Canis*, considerably lower and less overhanging than in *Felis* or *Viverra*. The acromion is much better developed than in *Canis;* apparently considerably more than in *Felis* or *Viverra*. Its tip is broken off, but it projects considerably beyond the glenoid cavity. The coracoid process is short but very distinct, as in *Felis* and *Viverra;* in *Canis* it is absent. The last two features are seen in *Didelphys*, to which the scapula has otherwise little resemblance.

The humerus most nearly resembles that of the domestic cat, but is somewhat more massive throughout and a little broader at the distal end. The shaft is comparatively straight, the deltoid crest scarcely more prominent than in *Felis*, although extending farther down the shaft. The supinator crest is a little higher than in *Felis domestica*, the trochlea is considerably broader, and the internal condyle and

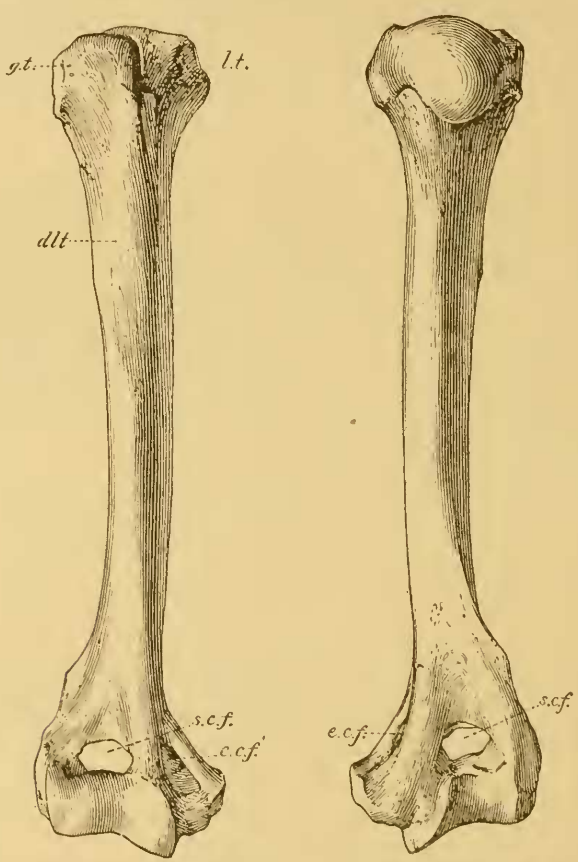


FIG. 15.—SINOPA GRANGERI, HUMERUS, ANTERIOR AND POSTERIOR VIEWS, NAT. SIZE. *g. t.*, GREATER TUBEROSITY; *dlt*, DELTOID CREST; *e. c. f.*, ENTEPICONDYLAR FORAMEN; *l. t.*, LESSER TUBEROSITY; *s. c. f.*, SUPRA-TROCHLEAR VACUITY.

entepicondylar foramen considerably wider. There appears to be a supratrochlear foramen, but of this I can not be certain. The shaft is somewhat straighter, the deltoid crest less developed than in *Canis*. *Daphænus* shows still more curvature of the shaft; the deltoid crest is higher and extends much farther down; the trochlea resembles that of *Sinopa*, but the internal condyle and the supinator ridge are less developed. The opossum humerus is widely different in form at the distal end, the internal and external condyles almost equally developed, the trochlea very wide and shallow, the inferior end of the deltoid crest very high and situate far down on the shaft.

Radius and ulna.—The shafts of these bones are nearly straight, with the olecranon in line with the ulnar shaft, as in the viverrines. In the cats and in *Daphænus*, as also in the opossum, the shafts are slightly convex forward; in *Canis* they are considerably bowed. The olecranon is rather long, and expanded anteroposteriorly, as in *Daphænus* and the viverrines; in the cats it is a little shorter and projects more anteriorly; in the opossum it projects more anteriorly and is much less expanded in an anteroposterior direction. The ulnar and radial shafts are about equally robust, as in *Daphænus* and the viverrines; the ulna is somewhat larger proportionately than in either, but not so robust as in *Didelphys*, and is expanded on the antero-internal side, next the radius, in a broad flat plate, thin distally, but with thickened margin toward the proximal part. This plate lies in the position of the interosseous membrane, and probably gave a rigid attachment for strong pronator muscles. It is not present in other carnivora, which I have examined, nor in *Didelphys*. In *Hyænodon* it has become narrower and much thicker, forming an integral part of the very robust ulnar shaft, but it is clearly indicated by the broad deep groove extending down the anterior face of the shaft.

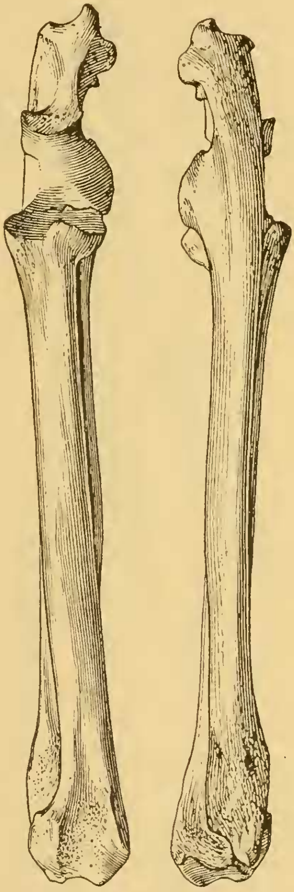


FIG. 16.—SINOPA GRANGERI, RADIUS AND ULNA, ANTERIOR AND POSTERIOR VIEWS, NAT. SIZE.

The distal end of the ulna resembles that of *Hyænodon* and the viverrines, and allowing for the great reduction in size in *Canis*, it resembles that genus, while it differs notably from *Daphænus* and the cats in the position of the cuneiform facet, which faces more distally (but not so much so as in *Hyænodon*), and is nearly continuous with the radial facet, while in *Daphænus* and the *Felidæ* it faces almost internally and stands on the end of a stout hooked process, separated by a deep groove from the radial facet.

The head of the radius has the same oval form as in *Hyænodon*, the ulnar facet being comparatively flat, permitting of but a limited degree of rotation, much less than in *Daphænus* or *Felis*, about as in *Canis*. The coronoid process is less prominent than in *Hyænodon*, much less than in *Daphænus* or *Felis*, somewhat more than in *Canis*.

The distal end of the radius likewise resembles *Hyænodon* and differs widely from *Daphænus* and the Felidæ, much less from the Canidæ, in the convex posterior surface, the slight development of the styloid process (moderately strong in the dogs, remarkably strong in *Daphænus*) and many details of form and arrangement of the processes and tendinal grooves.

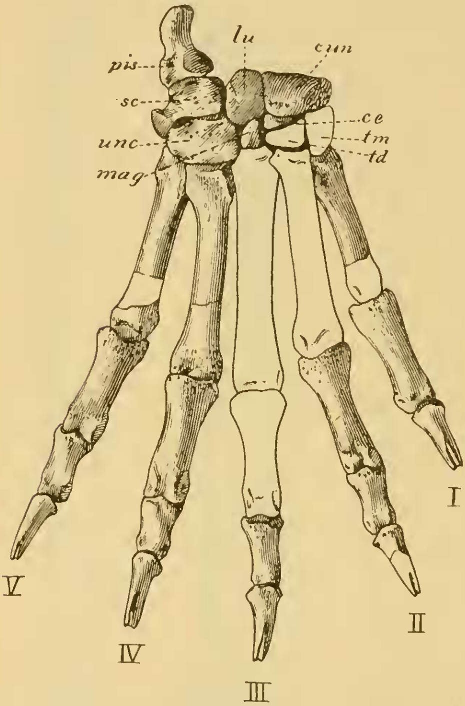


Fig. 17.—Sinopa grangeri fore foot, nat. size, dorsal view. *cc*, centrale; *cun*, scaphoid; *lu*, lunar; *mag*, magnum; *pis*, pisiform; *sc*, cuneiform; *td*, trapezoid; *tm*, trapezium; *unc*, unciform. The dorsal surface of the magnum is represented considerably too large, and the proximal facet of the lunar incorrectly defined so that it appears to extend over the whole dorsal surface of the bone.

Forefoot.—The entire carpus except the trapezoid and trapezium, the greater part of three metacarpals, and most of the phalanges are preserved. The carpus has the usual creodont characters of separate scaphoid, lunar, and centrale, small magnum, large unciform and cuneiform, etc. The centrale is of moderate size, and lies principally under the scaphoid, but toward the dorsal surface projects considerably under the lunar so that its small exposure on the dorsal face of the carpus lies equally beneath scaphoid and lunar.

The carpus is higher than in *Hyænodon*, but the bones have the same rather broad square character common to Hyænodonts, Oxyænids, and Mesonychids, which the writer has elsewhere explained as paralleling the ungulates.[a] The scaphoid is of moderate height and is principally supported by centrale and trapezium. The lunar is supported about equally by magnum and unciform. The cuneiform is

[a] Wortman, in criticising this passage, appears to have completely misunderstood my words, and supposed that by "podials" I meant claws! The parallelism with the ungulates does not of course involve relationship, but is due to a similar adaptation of the feet to use solely in locomotion. A later and less perfect parallelism in the podials is seen in the Canidæ, taking place after the consolidation of the scapholunar-centrale.

large, both broad and deep, lies mainly proximal to the unciform, nearly touches the lunar internally, and its ulnar facet faces chiefly proximal. The magnum, with very small dorsal surface, is much compressed laterally and strongly keeled on the proximal side toward the ventral surface. It carries no hook. The trapezoid is not preserved, but from the arrangement of the adjoining bones it appears to have been quite small, its height much less than in *Hyænodon*, with very slight contact with the magnum, a small dorsal-external contact with the scaphoid, and principally supporting the centrale. Its contact with the trapezium appears to have been lateral-superior. The trapezium is not preserved, but from other specimens it is known to have been rather large, not as high as in *Hyænodon*, and permitting a greater divergence and more freedom of motion of the pollex, which can hardly, however, be said to be even semi-opposable.

The metacarpals are five in number, all being of approximately equal robustness, but the laterals reduced in length, although much longer than in *Hyænodon*. The exact proportions can not be determined from this specimen, but apparently they were the same as in the manus of *Tritemnodon*. The fifth digit is restored somewhat too long in the drawing. In *Sinopa* and *Tritemnodon*, as in *Hyænodon*, the symmetry of the manus is pentadactyl with a tendency to tridactylism more marked in the oligocene genus. In the true Carnivora, and in the Mesonychidæ among Creodonts, the manus is constructed upon a tetradactyl symmetry.

The phalanges are not remarkable. The unguals are small, more compressed than in *Hyænodon*, and fissured at the tips.

The manus of *Tritemnodon* agrees in all its principal features with that of *Sinopa*, but differs in numerous small details of structure, the greater part of which are slight approximations toward the *Hyænodon* manus.

Hind limb.—The pelvis has the same proportions between pre- and post- acetabular regions as in *Hyænodon*, about the same as in the cat. The superior border of the ilium is considerably expanded, a remarkable character which finds its nearest analogue in the Phenacodontidæ, although seen to a less extent in *Hyænodon* and *Hoplophoneus*. In the modern Carnivora it is the inferior border of the ilium (below the primitive rod, and below the sacral articulation) which is expanded to a greater or less degree. The ischium is rather thin and slender and the pubis stout, as compared with modern Carnivora.

The femur is of moderate length, having about the same proportions as in *Hyænodon*. The upper part of the shaft has a considerable lateral curvature. The third trochanter is much better developed than in *Hyænodon*, and placed considerably lower down on the shaft than in *Daphænus* or *Hoplophoneus*. In modern Carnivora the third trochanter is absent and the shaft much straighter. In the Condylarthra it is much stronger and situate about the middle of the shaft, except in *Euprotogonia*, in which it is higher up. The distal end of the bone has a moderate lateral expansion and great vertical depth, as in *Hyænodon* and the Condylarthra, the rotular trochlea narrow and elongate, but not extending so far up on the anterior surface of the shaft

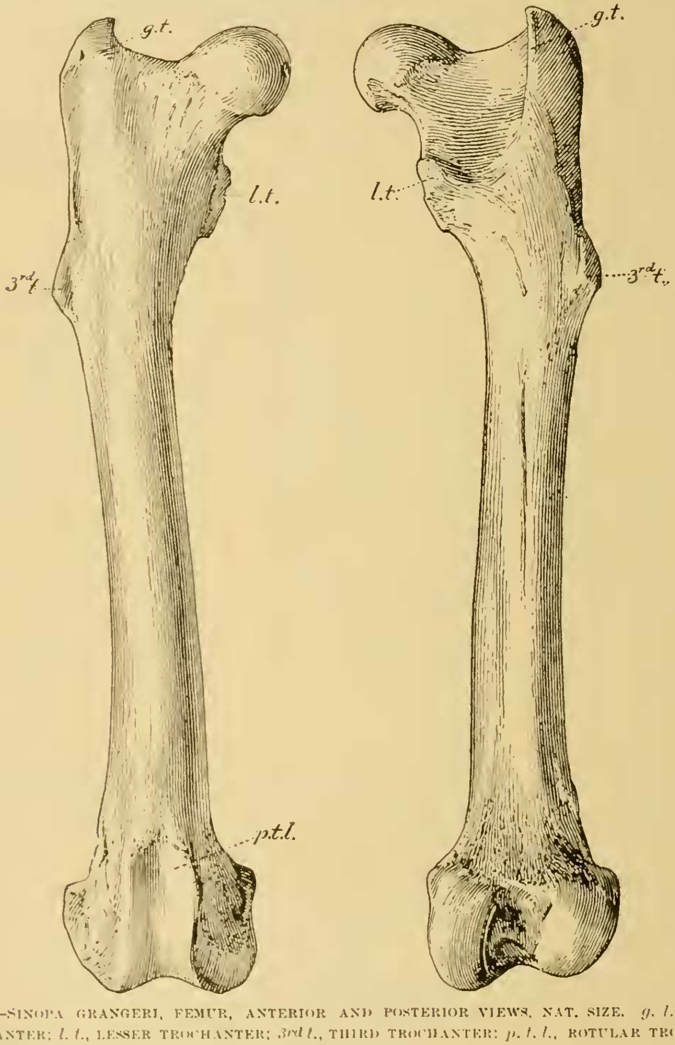


FIG. 18.—SINOPA GRANGERI, FEMUR, ANTERIOR AND POSTERIOR VIEWS, NAT. SIZE. *g. t.*, GREATER TROCHANTER; *l. t.*, LESSER TROCHANTER; *3rd t.*, THIRD TROCHANTER; *p. t. l.*, ROTULAR TROCHLEA OR GROOVE FOR THE PATELLA.

as in *Hyænodon*. In *Patriofelis* the femur has a much more massive shaft, the distal end is not so deep, the third trochanter is somewhat similar in development, and the curvature of the shaft about the same. *Oxyæna* has a weaker third trochanter, thicker shaft, and distal end more like the normal Carnivora type.

Tibia and fibula.—The proportion of these two bones is about as in *Hyænodon*, the fibular shaft less reduced than in modern carnivora, among which the viverrines offer the nearest approach, while *Daphænus* is decidedly nearer. The bones are proportionately shorter, with less rounded shafts than in the more modernized carnivora, e. g., *Canis* or *Felis*. The most marked peculiarity is the well-developed tibulo-calcanear facet, which is only a little less extensive than in *Hyænodon*.

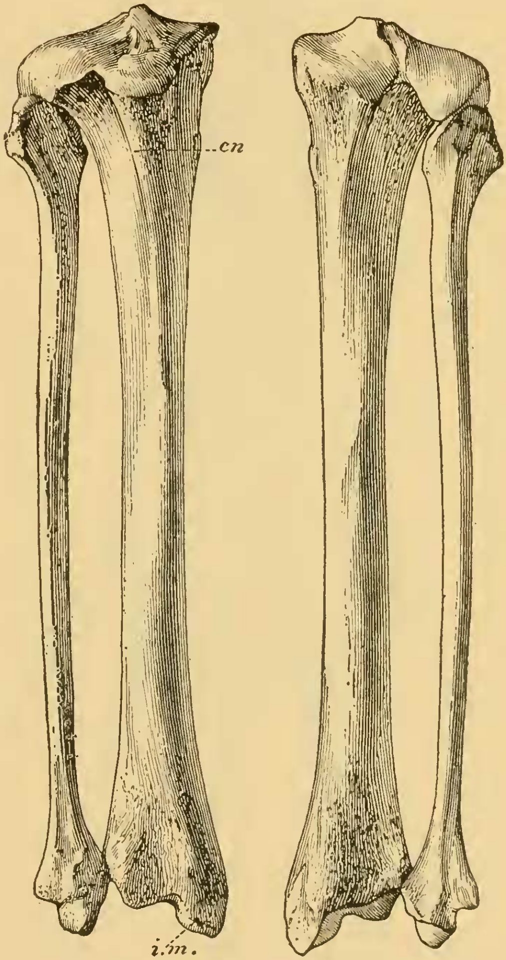


FIG. 19.—SINOPA GRANGERI, TIBIA AND FIBULA, NAT. SIZE, ANTERIOR AND POSTERIOR VIEWS. *cn*, CNEMIAL CREST ON ANTERIOR SURFACE OF TIBIA; *i. m.*, INTERNAL MALLEOLUS OF TIBIA.

Hind foot.—The pes is pentadactyle, and its symmetry is approximately mesaxonic, but less exactly so than in the manus, the first digit being shorter and more slender than the fifth, and the second somewhat shorter, although stouter, than the fourth, while the third projects beyond either, and is nearly, but not quite, symmetrical at its distal end. This symmetry agrees entirely with that of *Hyænodon* and differs radically from the paraxonic symmetry of manus and pes in the true Carnivora and the Mesonychidæ. In the Oxyænidæ the foot symmetry appears to be approximately as in the Hyænodontidæ, but the foot is broader and shorter, especially in *Patriofelis*, and the symmetry less noticeable in consequence.

The astragalus differs considerably from that of *Hyænodon*. The trochlea is not nearly so deep, the posterior tendinal groove is much deeper, the neck is longer, the head much broader, not nearly so deep, more convex laterally. The astragalar foramen is distinct, but very small, and I can not be certain that it is continuous through the bone.

The calcaneum has a considerably longer tuber than in *Hyænodon*, somewhat grooved on the superior surface of its distal end for the tendon of the plantaris, as in many modern carnivora. In *Hyænodon* the groove is absent. The cuboid is longer than in *Hyænodon* and has a considerable astragalar facet, which does not extend, however, to the dorsal surface. In *Hyænodon* this facet is smaller and farther removed from the dorsal surface of the bone. It seems to have been absent or indistinct in the specimens examined by Professor Scott. In the Oxyænidæ and Mesonychidæ it is much better developed. In modern carnivora it is absent, but it is moderately developed in *Daphænus*, although lateral instead of partly superior, as in Creodonta. The cuneiform bones are much as in *Hyænodon*, except that the entocuneiform is shorter and broader, its contact with Mt. II less, and the distal facet broader and more oblique. It is less elongate and very much broader than in modern Carnivora, and the distal facet retains much more of the primitive saddle-shaped curvature, thus permitting a greater degree of opposition of the first digit.

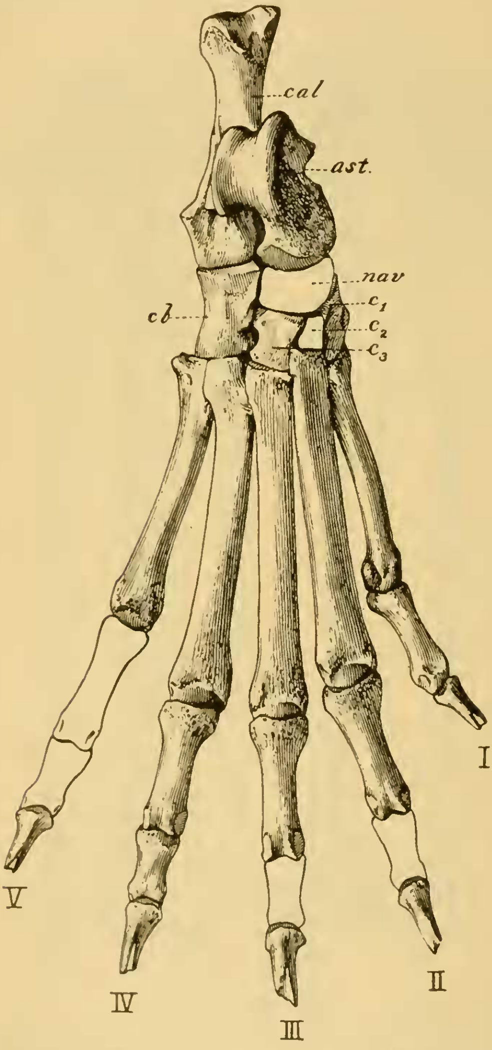


FIG. 20.—SINOPA GRANGERI. HIND FOOT, NAT. SIZE, DORSAL VIEW. *ast*, ASTRAGALUS; *cal*, CALCANEUM; *cb*, CUBOID; $c_{1, 2, 3}$, CUNEIFORM BONES; *nav*, NAVICULAR.

The metatarsals are somewhat less compressed and more slender than in *Hyænodon;* their relative proportions are noted above. The head of Mt. I is broader. In other respects there is very little difference. The phalanges resemble those of the forefoot, except in their larger size and somewhat more elongate proportions. The pes is by no means as long or compressed as in most modern Carnivora, and this, with the difference in symmetry, involves numerous small differences in construction and arrangement of the bones.

Tritemnodon closely resembles *Sinopa* in the structure of the hind limb, as shown by comparison of Doctor Wortman's description of the parts known to him and of the more complete specimens in the American Museum collections.

Comparisons of the appendicular skeleton.—In the characters of the fore and hind limb, *Sinopa* is in the main of the primitive creodont type, but shows an earlier stage of the cursorial adaptations of *Hyænodon*, and shares with that genus a number of peculiarities probably characteristic of the family. The long, narrow scapula, the expanded ilium, the depth of the distal end of the femur, the reduction of the deltoid and supinator ridges of the humerus, the squaring of the carpus and deepening of the astragalar trochlea and head, and in general the elongation of the limb bones, elongation and compression of the feet, are all differentiations from the primitive type, carried to but a slight extent in *Sinopa*, to a considerably greater extent in *Hyænodon*, paralleled in all the cursorial Carnivora and in the Condylarthra, and carried to a much greater extent in the cursorial Ungulata. On the other hand, the retention of the coracoid process and long acromion of the scapula, the comparatively long postacetabular region of the pelvis, the entepicondylar foramen on the humerus and the third trochanter on the femur, the stout ulna with its long olecranon, the unreduced fibula, the distinct centrale, the astragulo-cuboidal articulation, the large size of the lateral digits, and the moderately compressed claws, are apparently primitive creodont features not yet modified by the cursorial adaptation which had begun to show itself in the appendicular skeleton. Some of these characters are still retained by *Hyænodon*, and they are retained to a varying extent by the other creodont families and by the more primitive modern Carnivora. The mesaxonic manus and pes, the fibulo-calcanear articulation, and the broad flange on the radial side of the ulnar shaft, are apparently family characters of the Hyænodontidæ. The first and the last characters are also seen in the Phenacodontidæ, and the relative conditions of the appendicular skeleton in *Sinopa* and *Hyænodon* are exactly paralleled by the relative conditions in *Euprotogonia* and *Phenacodus*.

ANALYSIS OF THE CHARACTERS OF SKULL AND SKELETON.

Primitive mammalian features.—Skull elongate, brain-case small, sagittal and occipital crests strong, orbits situate above molars, hence lachrymal and superior process of jugal moderately expanded upon the face. Nasals somewhat expanded posteriorly. Tympanic bullæ not ossified. Teeth 44 in number, the molars tritubercular above, tuberculo-sectorial below, the premolars trenchant. Ribs short, sternum narrow, tail long and powerful, limbs rather short, flexible, feet pentadactyl, pollex and hallux divergent, centrale present, astragalus with shallow trochlea and round convex head; fibula little reduced, and ulna as stout as radius. Coracoid process on scapula.

Primitive eutherian features.—Dentition $\frac{3.1.4.3}{3.1.4.3}$. Angle of jaw not inflected. Sacrum of 3 vertebræ. No vertebrarterial foramen on seventh cervical.

Primitive carnivore features.—Incisors small, canines large, piercing. Parietal bones long, basicranial region long, mastoid exposure small, lateral. Posterior nareal canal long and deep. No false (alisphenoid) bulla. Dorsolumbar formula twenty. Lumbars very large and long, their zygapophyses large and very convex. Ungual phalanges bearing moderately compressed claws. A small contact between astragalus and cuboid. A third trochanter rather high up on shaft of femur.

Cursorial adaptations.—Limb bones elongate. Scapula long and narrow. Humerus with reduced deltoid and supinator crests. Ulna and radius with limited amount of pronation and supination. Carpus broad, its proximal articulations transverse. Ilium expanded, distal end of femur deep, astragalar trochlea somewhat excavated and extended posteriorly, and head somewhat deepened. Fore and hind feet somewhat compressed and apparently digitigrade.

Special hyænodont characters.—Molars developing a shear by extension of parastyle, especially on M $\frac{2}{3}$. Manus and pes mesaxonic. A fibulo-calcanear facet. Astragalo-cuboid facet reduced. Claws fissured (also in Mesonychidæ and Oxyænidæ).

Generic and specific characters.—These need not be repeated here, as they have been fully defined in an earlier section of this paper.

RELATIONSHIPS OF SINOPA.

The primitive mammalian features are predominant, as might be expected in a Middle Eocene animal. These features are found in all early mammals, whether Metatherians or Eutherians. *Sinopa* is, however, a typical Eutherian in the dentition, in the conformation of the angle of the jaw, and other characters of less importance. The primitive carnivore features are numerous and important, and amply demonstrate the pertinence of *Sinopa* to this order. The characters of the base and back of the skull especially distinguish it sharply from either marsupials or Insectivora. The cursorial adaptations in the limbs and feet are comparatively slight, but unmistakable. Along with the special hyænodont characters they demonstrate the position of the genus as a primitive member of the Hyænodontidæ. It stands directly ancestral to *Hyænodon* in all details of its structure and shows a considerable degree of progress from the primitive carnivore type toward the line which terminated in the large, highly specialized Hyænodons of the American oligocene. As has already been observed, the geological occurrence of the species of this phylogenetic line makes it improbable that *Hyænodon* was directly descended from any of the Middle Eocene species of *Sinopa;* it is more probably derived from a Lower Eocene or earlier species. Wortman has suggested *S. opisthotoma* as a possible ancestor, but this species does not entirely meet the required conditions.

The relationship to the carnivorous marsupials appears to be a remote one, despite a considerable degree of superficial resemblance, due chiefly to the retention of the primitive mammalian characters. In all marsupials the angle of the lower jaw is inflected, the molars number four, the premolars not more than three, the basicranial region is short and the mastoid exposure posterior and of large size, the carotid canal pierces the basisphenoid, the pterygoid processes of the alisphenoid and palatine are little developed, and more or less of a false bulla is formed; the dorsolumbar formula is 19, and there are numerous less important details of form and structure in the bones, showing that they are far removed from *Sinopa* or from any of the Creodonta. The dorsolumbar formula of *Mesonyx*, according to Wortman, was 19, as in the marsupials, and this genus also has a broad posterior expansion of the nasals; but in the much more important characters of the base and back of the skull, as in all other features of the skeleton, it is evidently of true carnivore affinities, somewhat disguised by a high degree of specialization in certain parts. In *Sinopa*, in *Oxyæna* and *Hyænodon*, and probably in *Patriofelis*, the only other creodonts in which the dorsolumbar formula is known, it is twenty, as in all Carnivora, and these genera have all evidently descended from primitive carnivore ancestors, whose principal distinctions are given above.

The Insectivora appear to be in many respects intermediate between Carnivora and marsupials, but how far they are actually so would be difficult to say. It is clear that the Creodonts are not nearly related to any living Insectivora, but we know so little about the past history of the insectivore group that we can not yet say whether it is really a homogeneous one or an arbitrary association of unrelated types. In the features of the base and back of the skull they differ very considerably from Carnivora and agree more or less with marsupials (the course of the carotid canal differs from either group). They have the Eutherian dental formula, a non-inflected angle of peculiar type in the lower jaw, etc.; these features characterize the most primitive and ancient known types as well as the modern ones.

The position and relationships of the Eocene Carnivora have been variously estimated by the different writers who have studied and described their remains. The incomplete specimens first found in the

Old and New Worlds were referred to the true Carnivora (Fissipedia); later on the great French palæontologists, Gervais and Gaudry, emphasized the affinities of some among them to the marsupials, a view adopted in a broad sense by Huxley and other authorities, but disputed by Filhol and most subsequent writers. In 1875 the accumulating new discoveries of material enabled Cope to reconstruct, from various forms referred to marsupials, Carnivora, and Insectivora, the group of *Creodonta*, with affinities to all three orders named, but more nearly related to the two latter, and containing the ancestral types of the modern Carnivora. Schlosser, in his monumental studies upon the fossil primates and unguiculates of Europe, regards the Creodonta as definitively related to the true Carnivora, excluding from the group a number of insectivore-like types which had been included by Cope. He divides them into Adaptiva and Inadaptiva, both springing from a common primitive creodont stem, the former approximately ancestral to the true Carnivora, the latter becoming extinct. This view is substantially indorsed by subsequent writers, with the exception of Wortman, who in his studies of Eocene Carnivora in the Marsh collection, appears inclined to lay emphasis, especially in the first part of his paper, upon the marsupial affinities of the group.

So far as I can understand Doctor Wortman's position, it seems to be that the creodonts and carnivores are two distinct branches, both derived from the Cretaceous marsupials exemplified by *Didelphops*, and that the modern carnivorous marsupials, except for the inflection of the jaw and suppression of the second set of teeth, are little altered from the Cretaceous ancestors of the placental Carnivora. Hence the Basal Eocene creodonts and carnivores are closely allied to the living marsupials, the Middle Eocene less nearly so, and in the Oligocene and later formations the modern carnivore stamp becomes more apparent.

The essential divergence of this view from that generally accepted is in the nearer alliance implied between marsupials and placentals. In Wortman's view the Carnivora, Creodonta, Insectivora, etc., arise each as a separate branch from the Cretaceous marsupials, which also persist little altered in the modern Polyprotodonts. If this be true, the modern groups of placentals are not more nearly related to each other than they are to the Polyprotodont marsupials, and their resemblances are all due to parallelism. This view is only held conjecturally in the case of other groups, but is quite specifically stated in regard to Creodonts and true Carnivores.

I do not think, however, that the evidence, even as stated by Wortman, supports this view, and quite naturally he is inclined to lay emphasis upon the marsupialoid features of the creodont skull. On the contrary, I think it is safe to say that if we set aside superficial and adaptive characters, and rest principally upon deep-seated resemblances such as are found in the characters of the base of the skull, the dental and dorsolumbar formulæ, etc., we find every known creodont very much nearer to the modern Carnivora than to the modern marsupials. On the other hand, the little that is known of Cretaceous marsupials bears distinctly the marsupial stamp in every detail and does not show any essential approach to the early placentals.